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"An Embolic Protection System"Related Applications

This application is related to, and claims the benefit of, the following patent applications, namely: U.S. Application No. 09/188,472 filed November 9, 1998, ^{U.S.P. 6,336,934} which claims priority from Irish Patent Application No. 970789 filed on November 7, 1997 and Irish Patent Application No. 980267 filed on April 8, 1998; International Application No. PCT/IE00/00045 filed on April 20, 2000; Irish Patent Application No. 2001/0258 filed on March 16, 2001; Irish Patent Application No. 2001/0260 filed on March 16, 2001; and Irish Patent Application No. 2001/0261 filed on March 16, 2001; all of which are hereby incorporated herein by reference in their entirety.

Introduction

This invention relates to a transvascular embolic protection system for safely capturing and retaining embolic material released during an interventional procedure while maintaining blood flow.

WO-A-99/23976 describes various embolic protection systems of this type. WO-A-99/51167 and WO-A-99/51166 describe delivery catheters for delivery of an embolic protection filter to a desired site in the vascular system. Various embolic filters are described in WO-A-00/67668), WO-A-00/67669 WO-A-00/67670 and WO-A-00/67671. A retrieval catheter for use with such embolic protection systems is described in WO-A-01/12082.

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There is an economical and clinical need to provide an improved embolic protection system which will be easy and convenient for a clinician to prepare for use, to deploy and to retrieve. In addition there is a need to provide such a system which will facilitate a wide range of clinical procedures to be carried out.

Statements of Invention

According to the invention there is provided an embolic protection system comprising:-

a guidewire for advancing through a vasculature, the guidewire having a distal end and a proximal end;

an embolic protection filter having a filter body with a distal end and a proximal end, the filter body providing for a collapsed configuration and an expanded deployed configuration;

the embolic protection filter body having a guidewire path for slidably receiving the guidewire to permit movement of the filter relative to the guidewire when the filter is in the collapsed configuration and the expanded deployed configuration;

a delivery catheter advanceable over the guidewire for delivery of the embolic protection filter; the delivery catheter having a proximal end and a distal end, the filter being deployed from the distal end of the delivery catheter into the expanded deployed configuration;

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a retrieval catheter advancable over the guidewire for retrieval of the filter, the retrieval catheter having a distal end and a proximal end; and

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engagement elements for engaging the embolic protection filter with the guidewire for retrieval of the filter into the retrieval catheter in the collapsed configuration.

10 In one embodiment of the invention the guidewire path is in isolation from the embolic material captured within the filter body.

In a preferred case the tubular guidewire path is defined by a tubular sleeve. Ideally the tubular sleeve extends from the proximal end to the distal end of the filter. Desirably the guidewire path is a tubular guidewire path.

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In another embodiment the engagement elements comprise a guidewire engagement element on the guidewire and a filter engagement element on the filter, the engagement elements co-operating to provide selective engagement and positioning of the filter with respect to the guidewire. Preferably the engagement element of the guidewire comprises a guidewire abutment on the guidewire.

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The guidewire abutment may be located at the distal end of the guidewire.

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The guidewire abutment may be located proximal of the distal end of the guidewire.

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In a particularly preferred embodiment the engagement element of the filter comprises a filter abutment on the filter.

The filter abutment may be a distal abutment on the filter.

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The filter abutment may be a proximal abutment on the filter.

Most preferably the tubular guidewire path is defined by a sleeve and the filter abutment is provided by the sleeve.

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In another embodiment of the invention the engagement elements comprise releasable locking elements. Preferably the releasable locking elements comprise a taper lock. Ideally the guidewire engagement element comprises a locking ring on the guidewire and the filter engagement element comprises a tapered surface of the filter, the locking ring having a tapered surface which is engageable with the tapered surface of the filter to lock the filter to the guidewire. Most preferably the locking ring is a split ring.

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In another case the embolic protection system includes a tube advancable over the guidewire, the locking ring being located between a distal end of the tube and the filter for retrieval of the filter.

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Desirably the releasable locking means includes a tether engageable with the filter for retrieving the filter into the retrieval catheter.

In a preferred embodiment the embolic protection system comprises deployment means for moving the collapsed filter relative to the distal end

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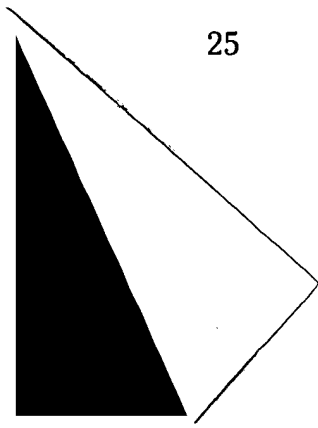
of the delivery catheter. Preferably the deployment means comprises a tube which is advancable over the guidewire for engagement with the proximal end of the filter, the tube being movable longitudinally relative to the delivery catheter for deployment of the filter from the distal end of the delivery catheter.

In another embodiment the embolic protection system includes loading means for loading the filter into the delivery catheter. Ideally the loading means comprises a funnel having a narrowed portion disposed at the distal end of the delivery catheter and an enlarged portion for receiving a proximal portion of the filter in the expanded configuration, the filter being progressively collapsed as it is moved through the funnel for loading into the delivery catheter.

In a further embodiment the embolic protection system includes engagement means for engaging the filter within the retrieval catheter. Preferably the engagement means comprises a frictional engagement between the filter body and an internal surface of the distal end of the retrieval catheter. Most preferably the engagement means comprises projections on the inner surface of the retrieval catheter adjacent the distal end thereof.

In another preferred embodiment the delivery catheter includes an elongate slot disposed in a first sidewall thereof at a first distal location which is spaced a relatively longer distance from the proximal end of the delivery catheter than from the distal end of the delivery catheter, and wherein the inner deployment catheter includes an aperture disposed in a second sidewall thereof at a second distal location which substantially corresponds

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with said first distal location for said elongate slot, thereby permitting co-operative movement of said filter with respect to said guidewire and associated delivery and deployment catheters for selective deployment of the filter while facilitating the rapid exchange of said catheter and filter assembly over a guidewire without the utilisation of exchange wires or extension wires.

The embolic protection filter may comprise a collapsible filter body, the proximal inlet end of the filter body having one or more inlet openings sized to allow blood and embolic material enter the filter body, the distal outlet end of the filter body having a plurality of outlet openings sized to allow through passage of blood but to retain undesired embolic material within the filter body. Ideally the filter comprises a collapsible filter support frame having a proximal end and a distal end, the filter support frame being movable between a collapsed position for movement during delivery through the vascular system and an extended outwardly projecting position to support the filter body in an expanded position thereby urging the filter body into apposition with the vasculature upon deployment. Most preferably the embolic protection system comprises a guide olive provided at the distal end of the filter body.

Desirably the embolic protection system comprises an inner elongate sleeve to which the filter body and the filter support frame are mounted, the sleeve having a proximal end and a distal end, the guide olive extending distally of the sleeve distal end.

the proximal end of the filter support frame and the inlet end of the filter body are preferably attached to the proximal end of the sleeve.

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The guide olive may be integral with the filter body.

Ideally the guide olive tapers distally inwardly.

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In another aspect the invention provides a method for the capture and removal of embolic material from a blood vessel during an interventional procedure comprising the steps of:-

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advancing a guidewire through a vasculature;

crossing a desired treatment location with the guidewire;

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introducing over the guidewire a collapsible embolic protection filter having a collapsed configuration, the collapsed configuration permitting delivery and withdrawal of the filter;

deploying the filter distal to the treatment location;

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carrying out the interventional procedure, embolic material generated during the treatment procedure being captured by the deployed filter;

advancing a retrieval catheter over the guidewire;

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collapsing the filter into the retrieval catheter and with it the captured embolic material;

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withdrawing the retrieval catheter and the collapsed filter from the vasculature leaving the guidewire in the vasculature.

5 In one embodiment of the invention the method comprises the step of providing a catheter over the guidewire after withdrawal of the retrieval catheter.

10 In another embodiment the method includes the step of moving the guidewire after withdrawal of the retrieval catheter and the collapsed filter from the vasculature to re-position the guidewire in the vasculature.

The catheter may be a catheter for delivery of a diagnostic medium.

15 The catheter may be a catheter for delivery of a lytic agent.

The filter is preferably slidably disposed on the guidewire when the filter is in the expanded deployed configuration.

20 In one preferred case the filter is rotatably disposed on the guidewire when the filter is in the expanded deployed configuration.

In a further embodiment the method includes the steps of:-

25 loading the filter in a collapsed configuration within a delivery catheter;

advancing the delivery catheter and filter over the guidewire to deliver the filter to a desired location; and

deploying the filter from the delivery catheter at the desired location.

Preferably the method includes the steps of:-

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collapsing the filter from an expanded configuration for loading the filter into the delivery catheter;

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the filter being expanded to a deployment configuration on release from the delivery catheter.

The treatment location may be a region of stenosis.

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In one embodiment the interventional procedure includes a balloon dilation of the stenosis while the filter is deployed.

In another embodiment the interventional procedure includes a stenting of the treatment location while the filter is deployed.

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According to another aspect of the invention there is provided a medical catheter for transvascular delivery and deployment of an embolic protection filter, the catheter comprising:-

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an outer catheter tube defining a distal end; and

an inner catheter tube defining a distal end;

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the outer tube being at least partially movable relative to the inner tube between a delivery configuration in which the distal end of the outer tube extends distally of the distal end of the inner tube to define a reception space for an embolic protection filter within the outer tube, and a deployment configuration in which the distal end of the inner tube extends distally of the distal end of the outer tube for deployment of the embolic protection filter ;

the inner catheter tube providing compressive resistance and the outer catheter tube providing stretch resistance.

In one embodiment the inner catheter tube at least partially comprises a relatively stiff core encased in a more pliable body.

In another embodiment the outer catheter tube at least partially comprises a relatively stiff core encased in a more pliable body.

The core is preferably oriented to prevent elongation of the outer catheter tube and/or compression of the inner catheter tube.

The core may comprise a mesh.

In one case the core comprises a plurality of longitudinally oriented strips of a stiff material. In another case the core comprises a plurality of circumferentially oriented strips of a stiff material.

The core may be of a metallic material. The metal is preferably stainless steel.

5 In a further aspect the invention provides an embolic protection device comprising:

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the frame having an intermediate section to urge the filter body in the expanded position into apposition with a vessel wall, and a proximal section extending radially inwardly of the intermediate section;

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at least part of the proximal section of the frame being spaced distally to accommodate inflow of embolic material through the inlet openings in the expanded position.

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In one embodiment of the invention the filter body comprises one or more linking webs between adjacent inlet openings, and a part of the proximal section of the frame extends radially inwardly in alignment with the webs.

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The frame proximal section preferably comprises one or more frame elements, at least one frame element providing the part of the proximal section spaced distally. Ideally at least one frame element provides the part of the proximal section extending radially inwardly in alignment with a linking web between adjacent inlet openings. Most preferably the number of frame elements is four, two frame elements extending radially inwardly in alignment with two webs between two inlet openings, and two frame elements spaced distally of the inlet openings.

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Desirably the support frame is gold-plated and electropolished.

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According to the invention there is also provided an assembly for loading a collapsible embolic protection filter into a catheter, the assembly comprising: -

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a catheter defining a reception space at a distal end of the catheter for receiving a collapsed embolic protection filter;

a separate removable pushing device for delivering the medical device into the reception space.

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5 In one embodiment the assembly comprises a separate loading device to collapse the embolic protection filter, the loading device defining an inlet end and an outlet end, the outlet end being configured for co-operative alignment with the reception space.

10 The pushing device may comprises a proximal stop for engagement with the embolic protection filter. Preferably the pushing device comprises a stem, the stem having a distal stop for engaging the embolic protection filter. Ideally the pushing device comprises a handle.

In another embodiment the loading device comprises means for radially compressing the embolic protection filter.

15 the loading device preferably comprises a funnel, the inlet end defining a larger cross sectional area than the outlet end. Ideally the loading device comprises a main support having a funnel-shaped bore formed from a frusto-conical embolic protection filter receiving portion terminating in a cylindrical portion formed by a loading tube projecting from the main support for alignment with the reception space before loading.

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The cone angle of the funnel is preferably between 15° and 65°. Most preferably the cone angle is between 35° and 45°.

25 In a preferred embodiment of the invention the loading device extends into the reception space.

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In another preferred embodiment of the invention the loading device extends around the outside of the reception space.

In a further embodiment the assembly comprises a tray, the tray comprising
5 a first retaining means for releasably supporting the pushing device in a disengaged position before delivering the embolic protection filter into the catheter. Preferably the assembly comprises a second retaining means for releasably supporting the loading device in co-operative alignment with the catheter during loading.

10 The retaining means may comprises a channel for receiving the loading device and/or the catheter and/or the pushing device, and at least one projection on the channel wall projecting inwardly for snap retention of the loading device and/or the catheter and/or the pushing device.

15 Ideally the tray comprises a liquid retaining bath formed by a recess in the tray, the bath having a depth sufficient to accommodate in a totally submerged state the reception space of the catheter and the embolic protection device for submerged loading of the embolic protection filter into
20 the reception space.

The tray preferably has a catheter holding channel communicating with the bath, the channel defining a pathway around the tray which supports the catheter in a loading position on the tray.

25 In another embodiment means for securing the catheter within the channel comprises a number of retainers spaced-apart along the channel, each retainer comprising two or more associated projections which project

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inwardly from opposite side walls of the channel adjacent a mouth of the channel, the projections being resiliently deformable for snap engagement of the catheter within the channel behind the projections.

- 5 A ramp may be provided at an end of the channel communicating with the bath to direct the reception space of the catheter towards a bottom of the bath.

10 Ideally means is provided within the bath for supporting the reception space of the catheter above the bottom of the bath.

Said supporting means is preferably a step adjacent the channel.

15 The first retaining means may be provided within the bath.

Desirably the assembly comprises a flushing means. Most preferably the flushing means comprises a syringe.

20 In a further aspect of the invention there is provided a method of loading an embolic protection filter into a catheter, the method comprising the steps of:-

providing an embolic protection filter, the embolic protection device being collapsible;

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providing a embolic protection catheter defining a reception space at a distal end of the catheter for receiving the collapsed embolic protection filter;

providing a pushing device for delivering the embolic protection filter into the reception space;

5 delivering the embolic protection filter into the reception space using
the pushing device; and

removing the pushing device from the reception space.

10 In one embodiment the method comprises the steps of :

providing a loading device to collapse the embolic protection filter,
the loading device defining an inlet end and an outlet end;

15 aligning the outlet end of the loading device in co-operation with the
reception space; and

delivering the embolic protection filter through the inlet end of the loading device and into the reception space.

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In a preferred case the catheter comprises an internal proximal stop, and the method comprises the step of moving the collapsed embolic protection filter proximally in the reception space using the pushing device to engage the internal proximal stop and disassociate the loaded catheter from the loading device before removing the pushing device.

The catheter may be constrained relative to the loading device before delivery of the embolic protection filter through the loading device into the

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reception space, and the method comprises the step of releasing the constraint to facilitate disassociation of the loaded catheter from the loading device.

- 5 In another embodiment the pushing device comprises a wire for threading through the embolic protection filter, the wire defining a distal stop for engaging the embolic protection filter.

- 10 The loading device may comprise an elongate neck at the outlet end, and the method comprises the step of at least partially positioning the elongate neck in the reception space before delivering the embolic protection filter into the reception space.

- 15 In a preferred embodiment the method comprises the step of flushing the embolic protection filter before delivering the embolic protection filter into the reception space.

- 20 Ideally the method comprises the step of flushing the catheter before delivering the embolic protection filter into the reception space.

- In a preferred case the catheter comprises an outer catheter tube and an inner catheter tube, the inner catheter tube defining the internal proximal stop.

- 25 Desirably both the inner catheter tube and the outer catheter tube are flushed before delivering the embolic protection filter through the loading device.

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In another aspect the invention provides a method of loading an embolic protection filter into a catheter, the method comprising the steps of : -

5 providing a embolic protection filter, the embolic protection filter being collapsible;

10 providing a catheter defining a reception space at a distal end of the catheter for receiving the collapsed embolic protection filter, the catheter comprising at least one internal proximal stop;

15 providing a loading device to collapse the embolic protection filter, the loading device defining an inlet end and an outlet end;

aligning the outlet end of the loading device with the reception space;

20 delivering the embolic protection filter through the loading device and into the reception space; and

25 moving the collapsed embolic protection filter towards its proximal end in the reception space to engage said at least one the internal proximal stop and disassociate the loaded catheter from the loading device.

In one embodiment the method comprises the steps of :-

providing a pushing device for delivering the embolic protection filter through the loading device and into the reception space, and for

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engaging the collapsed embolic protection filter with the internal proximal stop; and

5 removing the pushing device after disassociating the loaded catheter from the loading device.

10 In a preferred embodiment the pushing device comprises a wire for threading through the embolic protection filter, the wire defining a distal stop for engaging the embolic protection filter.

15 The loading device preferably comprises an elongate neck at the outlet end, and the method preferably comprises the step of at least partially aligning the elongate neck with the reception space before delivering the embolic protection filter through the loading device.

20 The method may comprise the step of flushing the embolic protection filter before delivering the embolic protection filter through the loading device.

The method may comprise the step of flushing the catheter before delivering the embolic protection filter into the reception space.

25 In a preferred embodiment the catheter comprises an outer catheter tube and an inner catheter tube, the inner catheter tube defining the internal proximal stop.

Desirably both the inner catheter tube and the outer catheter tube are flushed before delivering the embolic protection filter through the loading device.

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According to a further aspect of the invention there is provided a removable device for loading a collapsible embolic protection filter into a catheter, the device comprising a distal stop for releasably engaging with the embolic protection filter to push the embolic protection filter towards a proximal end of a catheter thereby loading the embolic protection filter into the catheter.

The distal stop is preferably provided on an elongate stem.

Most preferably the distal stop is integral with the stem.

In one case the distal stop comprises a step in the stem from a small diameter portion proximal of the step to a large diameter portion distal of the step.

The small diameter portion preferably has a diameter of approximately 0.014" (0.3556 mm).

The large diameter portion preferably has a diameter of approximately 0.018" (0.4572 mm).

The distal stop may be attached to the stem.

Ideally the stem comprises a wire.

The stem may comprise a low friction coating for ease of threading through the medical device. Ideally the coating is of polytetrafluoroethylene.

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In one case the device comprises a handle.

The invention provides a clinician with the freedom to select from different guidewires prior to selection of an embolic filter.

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Prior art assemblies suffer from the disadvantage that different guidewires cannot be used with a particular filter during an interventional procedure. A clinician is thus constrained to discard both the guidewire and the filter if the guidewire proves unsuitable, for example because it is too stiff or some other mechanical property is undesirable.

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An important advantage of the invention is that because the filter is not attached to the guidewire in a collapsed configuration for delivery, the guidewire which is first advanced through the vasculature has a lower profile. Therefore the guidewire alone can more easily navigate narrow and tortuous regions of the vasculature.

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Another important advantage of the invention is that because the filter is not fixed to the guidewire, if the deployed filter is mis-sized with respect to the region of the treatment site it is free to be carried distally by blood flow to a narrow section of the vasculature at which the filter effectively achieves apposition with the vessel wall. This ensures that all blood flow with entrained embolic material passes through the filter.

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Brief Description of the Drawings

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The invention will be more clearly understood from the following description of some embodiments thereof, given by way of example only, with reference to the accompanying drawings, in which: -

5 Fig. 1 is a perspective view of an embolic protection system pack;

Fig. 2 is a plan view of a delivery catheter of the embolic protection system;

10 Fig. 3 is a side, partially cross-sectional view of the delivery catheter of Fig. 2;

Fig. 4 is an enlarged view of part of the delivery catheter of Fig. 3;

15 Fig. 4A is a perspective , partially cut-away view of the delivery catheter;

Fig. 5 is a side, partially cross-sectional view of a handle piece of the delivery catheter of Fig. 3;

20 Fig. 6 is an enlarged view of part of the handle piece of Fig. 5;

Fig. 7 is an enlarged view of another part of the handle piece of Fig. 5;

Fig. 8 is a perspective view of a female luer of the delivery catheter of Fig. 3;

25 Fig. 9 is a plan view of an inner catheter of the embolic protection system;

Fig. 10 is a side, partially cross-sectional view of the inner catheter of Fig. 9;

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Fig. 11 is an enlarged view of part of the inner catheter of Fig. 10;

Fig. 12 is an enlarged view of another part of the inner catheter of Fig. 10;

5 Fig. 12A is a perspective, partially cut-away view of the inner catheter;

Fig. 13 is a plan view of the inner catheter and the delivery catheter assembled;

10 Fig. 14 is a side, partially cross-sectional view of the catheter assembly of Fig. 13;

Fig. 15 is an enlarged view of part of the catheter assembly of Fig. 14;

15 Fig. 16 is an enlarged view of another part of the catheter assembly of Fig. 14;

Fig. 17 is a side view of the catheter assembly of Fig. 14 with the inner catheter in a distal configuration of use;

20 Fig. 18 is a side, partially cross-sectional view of an embolic protection device of the embolic protection system;

Fig. 19 is a plan view of the embolic protection device of Fig. 18;

25 Fig. 20 is a side view of a pushing device of the embolic protection system;

Fig. 21 is a side, cross-sectional view of a part of the pushing device of Fig. 8;

FIG. 11

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Fig. 22 is a side, partially cross-sectional view of a loading device of the embolic protection system;

5 Fig. 23 is an enlarged view of the detail of the loading device of Fig. 22;

Fig. 23A is a cross sectional view of an alternative loading device;

10 Figs. 24 to 27 are schematic views illustrating release and flushing of the catheter assembly of Figs. 13 to 17;

Figs. 28 and 29 are schematic views illustrating release of the pushing device of Figs. 20 and 21;

15 Fig. 29A is a cross sectional view on the line AA in Fig. 29;

Figs. 30 to 32(b) are schematic views illustrating loading of the embolic protection device of Figs. 18 and 19 into the catheter assembly of Figs. 13 to 17;

20 Figs. 33 and 34 are schematic views illustrating disassociation of the loaded catheter assembly of Fig. 32(a) from the loading device of Figs. 22 and 23;

Figs. 35 is a side view of a guidewire of the embolic protection system;

25 Figs. 36 to 41 are schematic views illustrating delivery and deployment of the embolic protection device of Figs. 18 and 19 in a vasculature;

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Figs. 42 and 43 are schematic views illustrating treatment of the vasculature;

Figs. 44 to 47 are schematic views illustrating retrieval of the embolic protection device of Figs. 18 and 19 from the vasculature;

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Figs. 48 to 56 are side, partially cross-sectional views of other embolic protection devices of the embolic protection system;

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Figs. 57 and 58 are schematic views illustrating loading of embolic protection devices into the catheter assembly of Figs. 13 to 17;

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Figs. 59 to 61 are schematic views illustrating loading of the embolic protection device of Figs. 18 and 19 into the catheter assembly of Figs. 13 to 17 using a removable pulling device;

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Fig. 62 is a side view of the loaded catheter assembly;

Figs. 63 and 64 are schematic views illustrating loading of embolic protection devices into the catheter assembly of Figs. 13 to 17 using the pulling device of Figs. 59 to 61;

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Figs. 65 to 69 are schematic views illustrating retrieval of an embolic protection device from a vasculature;

Fig. 70 is a side view of another guidewire of the embolic protection system;

Figs. 71 to 74 are schematic views illustrating deployment of an embolic protection device in a vasculature;

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Figs. 75 and 76 are schematic views illustrating deployment of another embolic protection device in the vasculature using tethers;

5 Fig. 77 is a schematic view illustrating release of a tether of Figs. 75 and 76;

Figs. 78 to 81 are schematic views illustrating delivery and deployment of an embolic protection device of a rapid exchange embolic protection system in a vasculature;

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Fig. 82 is a side, partially cross sectional view of another embolic protection system;

Fig. 83 is a side, partially cross sectional view of a further embolic protection device; and

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Figs. 84 and 85 are cross sectional views of a distal portion of catheters.

Detailed Description

20 Referring to the drawings there is illustrated a transvascular embolic protection system according to the invention for safely capturing and retaining embolic material released during an interventional procedure while maintaining blood flow.

25 The embolic protection system comprises an embolic protection device 1, a delivery catheter 2 for delivery of the embolic protection device 1 to a desired location in the vascular system and a proximal stop for deployment of the embolic protection device 1. The device 1 is collapsible from an

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expanded deployed configuration to a retracted delivery configuration. The delivery catheter 2 has a pod 13 at the distal end to define a reception space for the embolic protection device 1 in the collapsed delivery configuration. The proximal stop in this case is provided by the distal end 27 of an inner catheter 25 which extends towards the pod 13 of the delivery catheter 2 for deployment of the embolic protection device 1 from the pod 13.

In use, the embolic protection device 1 is loaded into the pod 13 of the delivery catheter 2 which is delivered over a pre-positioned guidewire 99. At a desired location the inner catheter 25 is moved relative to the delivery catheter 2 to deploy the embolic protection device 1 from the pod 13. The delivery and inner catheters 2, 25 are then withdrawn leaving a bare guidewire 99 over which various devices such as a dilation balloon and /or a stent can be advanced to the treatment site. Embolic material dislodged during the treatment procedure(s) is collected in the embolic protection device 1. After treatment, the device 1 may be retrieved into a retrieval catheter 3. The guidewire 99 may be left in place for further catheter advancements or may be withdrawn with or subsequent to the withdrawal of the retrieval catheter 3.

Referring in particular to Fig. 1 a pack 4 is provided to safely store and prepare the embolic protection system for use. The pack 4 comprises a vacuum-formed tray 5, typically of PETG. The tray 5 has a channel 6 extending in a looped configuration around the tray 5 for receiving the delivery catheter 2. The delivery catheter 2 has a proximal end 11 and a distal end 12. A handle 14 is provided at the proximal end 11, and the inner catheter 25 which extends through the delivery catheter 2 has a luer 36 at the proximal end. The luer 36 is located in the tray 5 adjacent to the handle

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14. The pod 13 is provided at the distal end 12 of the inner catheter 2. A loading device 7 in the form of a funnel piece is mounted in the tray adjacent to and, in this case extending into the pod 13. The embolic protection device 1 is mounted in its expanded configuration in a well 90 in the tray 5 adjacent to and extending into the loading device 7. A pushing device 8 for loading the collapsible embolic protection device 1 is mounted in the tray 5 adjacent to the embolic protection device 1. A syringe 91 is also mounted in a recess 92 of the tray 5. The syringe 91 is used to flush the system and, after flushing, the pushing device 8 is used to push the embolic protection device 1 through the loading device 7 and into the pod 13 of the delivery catheter 2 in the collapsed configuration. The delivery catheter 2 is now ready for advancement over the guidewire 99.

Referring now to Figs. 2 to 8, the delivery catheter 2 is illustrated in more detail. The delivery catheter 2 comprises a tubular body 10, typically of polyimide, or nylon extending between a proximal end 11 and a distal end 12. At the distal end 12 of the tubular body 10 a pod 13 is provided, the pod 13 having a smaller wall thickness and in this case a larger internal diameter, as illustrated in Fig. 4, to define a reception space for receiving the embolic protection device in a collapsed configuration. The ^{handle} ~~hand~~ 14, illustrated in detail in Figs. 5 to 7, is attached to the proximal end 11 of the tubular body 10, with a strain relief member 15 extending from the handle 14 partially along the tubular body 10. The handle 14 defines a central lumen 16 extending between a proximal opening 17 and a distal opening 18. A side port opening 19 is provided in the handle 14, the side port 19 being in communication with the central lumen 16 (Fig. 3). A female luer 20, as illustrated in Fig. 8, is also provided, the luer 20 being fixedly mounted in the side port 19. A double-start thread is provided at the free end of the

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luer 20 for threadable attachment of, for example, a flushing syringe 91 to the luer 20.

5 In this case the proximal stop is provided by an inner catheter 25. As illustrated in Figs. 9 to 12, the inner catheter 25 comprises a tubular body extending between a proximal end 26 and a distal end 27. The tubular body comprises an inner tubular stem 28 extending between the proximal end 26 and the distal end 27, and an outer tubular stem 29, typically of polyimide, extending from the proximal end 26 only partially along the inner stem 28, as illustrated in Fig. 10. The outer stem 29 terminates in a protruding O-ring shoulder 30. An annular collar 31 is slidably mounted to the outer stem 29 proximally of the O-ring shoulder 30 (Fig. 12). The female winged luer piece 36 is attached to the proximal end 26 of the stems 28, 29 by means of a flair connector 32. The winged luer 36 defines a central lumen 33 extending between a proximal opening 34 and a distal opening 35.

As illustrated in Figs. 13 to 17, the inner catheter 25 is configured for insertion through the proximal opening 17 of the handle 14 and advancement through the handle 14 and the tubular body 10 until the collar 31 engages the handle 14 (Fig. 15) in the region of the proximal opening 17. The collar 31 is fixedly attached within the proximal opening 17 of the handle 14.

25 The inner catheter 25 is slidable relative to the delivery catheter 2 between a retracted position, as illustrated in Fig. 14, in which the distal end 27 of the inner catheter 25 is proximal of the pod 13 defining the reception space in the delivery catheter 2 (Fig. 16), and an extended position, in which the

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distal end 27 of the inner catheter 25 extends distally of the pod 13 of the delivery catheter 2 (Fig. 17). Movement of the inner catheter 25 proximally relative to the delivery catheter 2 is limited by engagement of the O-ring shoulder 30 with the collar 31 (Figs. 14 and 15).

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The pod 13 of the delivery catheter 2 and the inner stem 28 of the inner catheter 25 at least partially comprise a stiff core, for example of a metallic material, such as stainless steel, encased in a more pliable body, for example of a plastics material such as polyimide. The cores comprise a mesh of longitudinally oriented strips of the stiff material and circumferentially oriented strips of the stiff material.

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Accurate delivery of a filter to its intended location (a non-diseased vessel area) is a particularly important concern in tortuous anatomy where there is a limited area of non-diseased vessel. The accuracy of deployment is related to the build up of potential strain energy in delivery catheter systems. This strain energy is primarily a combination of strain energy produced in the outer and inner shaft during the deployment action. The designs described below referring in particular to Figs. 4A and 12A detail a novel solution to these problems.

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During the deployment action the outer shaft or delivery catheter 2 is subjected to high levels of tensile strain. The design/construction of the outer shaft 2 is such that the amount of strain energy that can be stored within the outer shaft is minimised. Low flexural stiffness is also desirable in catheter design to ensure good catheter flexibility, trackability and low insertion forces. These attributes are achieved by incorporating high tensile elements 21 within the wall construction of the outer shaft 2. These high

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5 tensile elements 2 can be high tensile longitudinal steel/wires as shown in the example below or they may be flexible high tensile wires or fibers, carbon fibers and or kevlar fibers. These fibers/wires are contained within the wall 22 of the catheter which may be a polymeric material (detailed in Fig. 4A is a polyimide wall). These wires/fibers provide the outer shaft with high tensile modulus (minimal stretch) which results in a shaft that can not store much strain energy. The inclusion of the above high tensile elements 21 allows for a low profile outer shaft 2. This low wall thickness outer catheter shaft therefore also has low flexural stiffness, good flexibility, trackability and subsequently low insertion force. The inner surface 23 of the lumen of this shaft 2 is a low friction (PTFE) material to minimise the friction strain energy incurred during the deployment action.

15 During the deployment action the inner catheter shaft 25 is subjected to high levels of compression strain. The design/construction of the inner shaft 25 is such that the modulus of compression is high which reduces the amount of strain energy that can be stored within the inner shaft 25. This is achieved by incorporating elements 24 with high compression modulus. These elements are contained within a material matrix 24A that further enhances the compression modulus of the inner shaft 25. The inclusion of the above high compression elements allows for a low profile outer shaft. The low wall thickness inner shaft will therefore also have low flexural stiffness, good flexibility and trackability. The example illustrated in Fig. 14A is a high compression modulus steel wire braid 24 contained within a polymeric matrix 24A. The inner lumen of the shaft 25 is made of a low friction (PTFE) material layer 24B. The outer surface of the shaft 25 is also provided with a low friction (FEP) material layer 24C. The layers 24 B and 24C ^{minimize} minimise the frictional strain energy incurred during delivery and

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deployment. Due to the combination of the above inner and outer shaft
2,25 the amount of strain energy that can be stored within the system during
use is very low. Due to the low strain energy build up within the system a
precise, controlled, low force deployment is achieved even in difficult vessel
5 paths.

In this case, the embolic protection device 1 comprises a collapsible filter
element 40 for delivery through a vascular system of a patient and
deployment at a desired location in the vascular system. Figs. 18 and 19
10 illustrate the filter element 40 in detail.

The filter element 40 comprises a collapsible filter body 41, a collapsible
filter support frame 42 contacting the filter body 41, and an inner elongate
sleeve 43 to which both the filter body 41 and the frame 42 are mounted. A
15 proximal end 44 of the filter body 41 and a proximal end 45 of the frame 42
are both fixedly attached to a proximal end 46 of the sleeve 43, in this case
by means of an adhesive bond. A distal end 47 of the filter body 41 and a
distal end 48 of the frame 42 are free to slide over a distal end 49 of the
sleeve 43.

The filter body 41 has a proximal inlet end and a distal outlet end. The inlet
end of the filter body 41 has one or more, in this case two, large inlet
openings 50, and the outlet end has a plurality of, in this case approximately
three hundred, small outlet openings 51 sized to allow through passage of
25 blood but to retain undesired embolic material within the filter body 41.

The filter support frame 42 is movable between a collapsed position for
movement of the filter element 40 through a vascular system and an

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extended outwardly projecting position to support the filter body 41 in an expanded position. The frame 42 has a distal section 52, an intermediate section 53 for urging the filter body 41 in the expanded position into apposition with a vascular vessel wall, and a proximal section 54 extending
5 proximally and radially inwardly of the intermediate section 53 (Figs. 18 and 19).

At least part of the proximal section 54 of the frame is spaced distally of the inlet openings 50 in the filter body 41 to accommodate inflow of embolic
10 material through the inlets 50 and into the expanded filter body 41. The filter body 41 comprises one or more, in this case two, linking webs 55 between adjacent inlets 50, and a part of the proximal section 54 of the frame extends radially inwardly in alignment with the webs 55, as illustrated
15 in Fig. 19, to avoid occluding the inlets 50 to the filter body 41 when the filter body 41 is in the expanded position. In this manner the possibility of embolic material becoming caught or hung-up on the proximal section 54 of the frame as the embolic material flows distally through the inlet
openings 50 is ^{minimized} ~~minimised~~.

20 The proximal section 54 of the frame comprises one or more frame elements, in this case four. At least one frame element, in this case two, provides the part of the proximal section 54 which is spaced distally of the inlets 50, and at least one frame element, in this case two, provides the part
25 of the proximal section 54 extending radially inwardly in alignment with the webs 55.

The proximal section of the frame runs generally parallel with a vessel wall and then turns radially inwards. The proximal arm(s) of the frame have a

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section that is displaced distally. The advantage of this displacement is that it creates an inlet path which is offset and therefore larger.

The frame elements are preferably of a shape memory material, such as Nitinol, or of a superelastic material, and may have a plating of gold or other dense material around the Nitinol. The frame elements facilitate movement of the frame 42 between the collapsed position and the extended outwardly projecting position. The frame 42 is electropolished.

The sleeve 43 defines a lumen 56 extending therethrough for exchange of the filter element 40 over the guidewire 99. The distal end 49 of the sleeve 43 is engageable with a stop such as a stop on the guidewire 99. This is particularly useful for retrieval of the filter element 40 from a vascular system. The sleeve 43 is typically of polyimide.

The sleeve 43 acts as a barrier between the lumen 56 through which a guidewire may be exchanged, and the internal annular volume of the filter body 41 within which embolic material is retained. In particular, the proximal end 46 of the sleeve 43 is proximal of the inlets 50, and the distal end 49 of the sleeve 43 is distal of the small outlets 51. This ensures that all blood flows into the filter body 41 through the inlets 50, through the filter body 41 and out of the filter body 41 through the small outlets 51 which are sized to retain undesired embolic material within the filter body 41. The sleeve 43 prevents escape of any embolic material from the filter body 41 into the lumen 56, for example, during exchange of medical devices over a guidewire received within the lumen 56, or during retrieval of the filter element 40.

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A guide olive 57 is provided for atraumatic delivery of the filter element 40 through a vascular system, the guide olive 57 forms an extension of the distal end 47 of the filter body 41 and tapering distally inwardly for a smooth transition profile. In this case, the guide olive 57 is integral with the filter body 41 and is of the material Pellethane. As illustrated in Figs. 18 and 19, the guide olive 57 extends distally of the distal end 49 of the sleeve 43.

In use, the region of a vasculature in which the filter element 40 is deployed is substantially straight for a length at least equal to the longitudinal length of the filter element 40 to ensure apposition of the filter body 41 with the vasculature wall. By directly mounting the guide olive 57 at the distal end 47 of the filter body 41, the overall longitudinal length of the filter element 40 is reduced to define a longitudinally compact filter element 40. Thus, the user has greater freedom when choosing a site in a vasculature to deploy the filter element 40 because the length of the vasculature which is required to be straight is correspondingly reduced.

As illustrated in Figs. 18 and 19, the distal end 48 of the frame 42 acts to reinforce the proximal section of the guide olive 57 and prevents flaring of the sleeve 43. The guide olive 57 has a soft distal tip 58..

Two gold marker bands 59, 60 are provided mounted to the sleeve 43. One marker band 59 is fixedly attached to the olive 51 and one marker band 60 is fixedly attached to the proximal end 45 of the frame 42. The marker bands 59, 60 assist in visualisation of the filter element 40 during an interventional procedure.

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5 A transition element 61 is fixedly mounted to the proximal end 46 of the sleeve 43, in this case by means of an adhesive bond. The transition element 61 is sized to fit inside the lumen of the delivery catheter 2 to provide a smooth stiffness transition and prevent kinking.

10 Referring now to Figs. 20 and 21, the pushing device 8 for loading the collapsible filter element 40 into the pod 13 of the delivery catheter 2 is illustrated. The pushing device 8 comprises a handle 70 for gripping the pushing device 8 and an elongate stem in this case provided by a wire 71, extending from the handle 70 for threading through the lumen 56 of the filter element 40. The wire 71 defines a distal stop 72 for releasably engaging with the distal end 49 of the sleeve 43 of the filter element 40 to push the filter element 40 into the pod 13 of the delivery catheter 2.

15 As illustrated in Fig. 21 the distal stop 72 is provided by an end 74 of an outer hypotube 73 which extends from the handle 70 partially along the wire 71. The free end 74 of the hypotube 73 forms a step from the small diameter wire 71 proximal of the step to the larger diameter hypotube 73 distal of the step. The small diameter is preferably approximately 0.014" (0.3556mm), and the large diameter is preferably approximately 0.018" (0.4572mm). The hypotube 73 may be attached to the wire 71 by any suitable means, such as an adhesive means, or a mechanical keying means, or by brazing, or soldering, or welding, or by any other suitable means.

25 The wire 71 may have a low friction coating, for example of polytetrafluoroethylene, for ease of threading of the wire 71 through the filter element 40. The handle 70 facilitates ease of gripping and of use of the pushing device 8.

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It will be appreciated that the distal stop 72 may be provided integral with the wire 71, for example by machining a step in the wire 71.

- 5 It will further be appreciated that the large diameter portion distal of the step may be only a locally defined feature on the wire 71 that does not extend distally to the handle 70.

10 The loading device 7 is illustrated in detail in Figs. 22 and 23. The loading device 7 defines a funnel having an inlet end 80 and an outlet end 81, the inlet end 80 defining a larger cross-sectional area than the outlet end 81, and the outlet end 81 being configured for co-operative alignment with the reception space of the delivery catheter 2.

15 The loading device 7 has means for radially compressing the filter element 40 from the extended outwardly projecting position to the collapsed position. In this case, the loading device 7 comprises a main support 82 having a funnel-shaped bore formed from a frusto-conical filter element receiving portion terminating in a cylindrical portion formed by a thin walled
20 loading tube 83 projecting from the main support 82 for positioning within the reception space of the delivery catheter 2.

The cone angle of the bore is chosen from an angle in the range of between 15° and 65°, preferably between 35° and 45°.

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The loading tube 83 is preferably formed from polyethyleneterephthalate (PET), and is mounted on a metal spigot 84, typically a grit blasted hypotube, by a combination of a polyolefin shrink tube bond and an

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adhesive bond. The metal spigot 84 is adhesively fixed to the main support 82 which is formed from "Perspex" or a similar material. The loading tube 83 may be coated with a lubricant.

5 Referring to Fig. 23A there is illustrated an alternative loading device 85 in which an outer support 86 is provided around the pod 13 of the delivery catheter 2. A smooth transition is provided by a funnel section 87 and the distal end of the pod 13. The area between the outer support 86 and the pod 13 may be a wetted annular space for ease of mounting and demounting.

10 Referring to Figs. 1 and 24 to 29, the tray 5 will now be described in more detail. The tray includes integral projections 9 that extend into various recesses. The projections 9 releasably support the loading device 7 in co-operative alignment with the delivery catheter 2 before loading and during the loading procedure. In particular, the loading device 7 is supported with the loading tube 83 extending proximally into the reception space of the delivery catheter 2 before loading and during the loading procedure. In addition, the projections 9 on the channel wall are configured to releasably support the pushing device 8 in a position in which the distal stop 72 does not engage the filter element 40 before the loading procedure commences.

20 The projections 9 are also configured to releasably support the luer 20 of the delivery catheter 2 in the horizontal position illustrated in Figs. 1 and 24. In this position it is not possible to slide the delivery catheter 2 proximally in the channel 6, or, in the configuration illustrated, to flush the delivery catheter 2 through the luer 20.

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A liquid retaining bath 90 is provided by recesses in the tray 5, the bath 90 having a depth sufficient to accommodate in a totally submerged state the reception space of the delivery catheter 2 and the filter element 40 for submerged loading of the filter element 40 through the loading device 7 and into the pod 13 of the delivery catheter 2. As illustrated in Fig. 1, the channel 6 communicates with the bath 90, and a ramp is provided at an end of the channel 6 communicating with the bath 90 to direct the reception space downwards towards the bottom of the bath 90 but supporting the pod 13 of the delivery catheter 2 above the bottom of the bath 90 by means of a step.

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The syringe 91 is provided for flushing the delivery catheter 2, the inner catheter 25, the loading device 7 and the filter element 40. The recess 92 is provided in the tray 5 for snap retention of the syringe 91 before use.

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The components of the embolic protection system are placed in the pack 4 in the following manner. The loading device 7 is snapped into place in the channel 6, with the projections 9 releasably supporting the loading device 7 in the position illustrated in Fig. 1.

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The inner catheter 25 is inserted through the proximal opening 17 of the handle 14, and advanced through the handle 14 and the tubular body 10 until the collar 31 engages the proximal opening 17 of the handle 14. The collar 31 is fixedly attached within the proximal opening 17 of the handle 14 by pushing the collar 31 home to create an interference fit between the collar 31 and the proximal opening walls. This catheter assembly is then looped through the channel 6 and held in place so that the loading tube 83 of the loading device 7 extends proximally into the pod 13 of the delivery catheter 2.

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The wire 71 of the pushing device 8 is then threaded through the filter element 40, a proximal end of the wire 71 is inserted through the loading device 7 and extended partially through the inner catheter 25. The handle 70 is snapped into place in the channel 6 by the projections 9. In this configuration the filter element 40 is slidable over the wire 71 but is normally positioned within the bath 90, as illustrated in Fig. 1. The projections 9 retain the pushing device 8 in a position in which the distal stop 72 is spaced distally of the bath 90, and so the distal stop 72 does not engage the filter element 40 in this storage configuration, as illustrated in Fig. 1.

The syringe 91 is snapped into place in the recess 92, and the assembled pack 4 is now ready to be sealed and stored until required for use.

In this storage configuration the filter element 40 is in the expanded configuration. This is an advantageous arrangement. If the filter element 40 was loaded into the delivery catheter 2 and stored in the collapsed position for a long period of time, the filter element 40 would be subject to material deformation, in particular to material creep. The assembled pack 4 of the invention may be safely stored for long periods in a packaged configuration without risk of filter element material deformation. The pack 4 is placed in a pouch and sealed.

When the assembled pack 4 is required for use, the seal is broken, the pack 4 is removed and the syringe 91 is removed from the recess 92. The luer 20 of the delivery catheter 2 is rotated through 90° in a "bolt-action" to release the luer 20 from the snap-fit retaining projections 9 in the tray 5, as

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illustrated in Figs. 24 and 25. The delivery catheter 2 is now slidable proximally in the channel 6, and the luer 20 is now accessible for flushing (Fig. 25). The syringe 91 is used to flush the delivery catheter 2 through the luer 20 (Fig. 26) and to flush the inner catheter 25 through the proximal opening 34 in the female luer piece 36 of the inner catheter 25 (Fig. 27). A saline solution is generally used for flushing the catheters 2, 25. The syringe 91 is also used to fill the bath 90 with saline solution, thereby immersing the filter element 40, the reception space of the delivery catheter 2 and the loading device 7 in the saline solution. This ensures all removed from the system.

This flushing step is performed shortly before intended use. The filter element 40 is completely visible and accessible to the user during prepping. In this way, the user can squeeze or pinch parts of the filter element 40 to ensure the filter element 40 is completely flushed of air. This is difficult if the filter element 40 was loaded into the delivery catheter 2 upon assembly and stored for a potentially long period in the collapsed position.

The flushed filter element 40 is now ready for loading into the pod 13 of the delivery catheter 2. The pushing device 8 is rotated through 90° in a "bolt-action" to release the handle 70 from the snap-fit retaining projections 9 in the tray 5, as illustrated in Figs. 28 and 29. In this configuration the pushing device is still retained to the tray (Fig. 29A). The pushing device 8 is now free to slide proximally in the channel 6 (Fig. 30), until the distal stop 72 engages with the distal end 49 of the sleeve 43 of the filter element 40 (Figs. 31(a) and 31(b)). Continued pushing of the pushing device 8 will push the filter element 40 proximally towards the loading device 7 (Fig. 31(a)), through the loading device 7, thereby collapsing the filter element 40 from the extended

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outwardly projecting position of Fig. 31(a) to the collapsed position of Fig. 32(a), and into the pod 13 of the delivery catheter 2 (Fig. 32(a)) until the filter element 40 abuts the distal end 27 of the inner stem 28 of the inner catheter 25. Further pushing of the pushing device 8 moves the collapsed
5 filter element 40 and the inner catheter 25 proximally until the O-ring shoulder 30 of the inner catheter 25 abuts the annular collar 31 fixed in the proximal opening 17 of the handle 14, as illustrated in Figs. 14 and 15. An O-ring 39 is also provided between the shoulder 30 and the collar 31.

10 The loading device 7 has thus far remained in co-operative alignment with the delivery catheter 2. Because the luer 20 of the delivery catheter 2 has been released from the snap-fit retaining projections 9 in the tray 5, as illustrated in Fig. 32(b), the catheter assembly is free to slide proximally in the channel 6 away from the loading device 7. When the pushing device 8
15 is further pushed proximally, this causes the inner catheter 25 to move proximally and with it the delivery catheter 2 due to the engagement of the O-ring shoulder 30 with the handle 14. In this manner, the delivery catheter 2, the inner catheter 25 and the collapsed filter element 40 are all moved together proximally away from the loading device 7, and thereby the loaded
20 catheter assembly is disassociated from the loading device 7 (Fig. 33).

The loaded catheter assembly is then removed from the channel 6 leaving the loading device 7 and the pushing device 8 behind in the channel 6. The assembly of the loaded delivery catheter 2 and the inner catheter 25, as
25 illustrated in Fig. 34, is now ready for insertion into a vascular system of a patient.

[illegible]

10 In addition, the loaded filter element 40 is not attached or associated in any way with the pushing device 8. Thus, the user is free to choose any suitable guidewire, as desired, for subsequent delivery of the filter element 40 through a vascular system of a patient.

25 In this case the distal stop 101 is provided by a wire coil 102 fixedly attached around the distal end 100 of the guidewire 99 (Fig. 35). The coil 102 has a larger outer diameter than the bare portion of the guidewire 99 to define a step from the small diameter bare portion of the guidewire 99 to the large diameter coil portion of the guidewire 99. The small diameter is preferably

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approximately 0.014" (0.3556 mm), and the large diameter is preferably 0.018" (0.4572 mm). A curve is typically formed towards the distal end 100 of the guidewire 99 to facilitate navigating and/or positioning the guidewire 99 in a vasculature.

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The coil 102 may be attached to the small diameter portion of the guidewire 99 by an adhesive means, or by a mechanical keying means, or by brazing, or soldering, or welding, or by any other suitable means of attachment.

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In this case, the guidewire 99 is partially of stainless steel, and partially of a radiopaque material to aid the user in positioning the guidewire 99 accurately in a vasculature. The guidewire 99 has a coating of a low friction material, for example of a fluoropolymer such as polytetrafluoroethylene, or of a silicone material, or of a hydrophilic material, for ease of advancement of the guidewire 99 through a vasculature and ease of exchange of the filter element 40 and /or other medical devices over the guidewire 99.

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As illustrated in Fig. 35, the large diameter coil 102 extends distally of the step to the distal end 100 of the guidewire 99. However it will be appreciated that the large diameter portion of the guidewire 99 may extend distally of the step only a part of the distance to the distal end 101 of the guidewire 99. The large diameter portion may taper distally inwardly back to the small diameter in an arrow-head type shape or by gradually tapering.

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Referring now to Figs. 36 to 41, delivery and deployment of the filter element 40 at a desired location within a vasculature 110 is illustrated. The guidewire 99 will be selected to suit the geometry of the vasculature 110 to be negotiated, and/or the disease site, and/or the preference of the user.

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The guidewire 99 is firstly inserted on its own into the vasculature system of a patient and advanced through the vasculature 110 until the distal stop 101 of the guidewire 99 is distal of a treatment site such as a region of stenosis 111 in the vasculature 110 (Fig. 36).

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The curved distal end 100 of the guidewire 99 is often anchored in a bend in the vasculature 110 distally of the stenosed region 111 (Fig. 41) to facilitate some straightening of the anatomy by the user prior to delivery of the filter element 40.

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The loaded delivery catheter assembly of Fig. 34 is then inserted into the vasculature system and advanced over the guidewire 99 through the vasculature 110, until the pod 13 of the delivery catheter 2 with the collapsed filter element 40 therein is positioned at a desired location of the vasculature 110 distally of the stenosed region 111 (Fig. 37). At least part of the filter element 40, in this case part of the distal end 58 of the guide olive 57, protrudes distally out of the pod 13 of the delivery catheter 2 during advancement of the delivery catheter 2 through the vascular system to minimise trauma to the vessel walls. The olive also provides a stiffness transition.

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The delivery catheter 2 is retracted while maintaining the position of the inner catheter 25 (Fig. 38). In this way the distal end 27 of the inner stem 28 of the inner catheter 25 acts as a proximal stop against which the transition element 61 of the filter element 40 abuts, thus the distal end 27 of the inner stem 28 of the inner catheter 25 prevents retraction of the collapsed filter element 40 with the delivery catheter 2. As the restraining delivery catheter 2 is withdrawn, the filter element 40 is freed to expand from the collapsed,

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delivery configuration to the extended, outwardly projecting position of Fig. 39.

The filter element 40 may alternatively be deployed by advancing the inner catheter 25 while maintaining the position of the delivery catheter 2. In this case the distal end 27 of the inner stem 28 of the inner catheter 25 effectively acts as a pusher to eject the collapsed filter element 40 from the pod 13 of the delivery catheter 2, and thereby facilitate expansion of the filter element 40 to the deployed configuration of Fig. 39.

It will be appreciated that the filter element 40 may be deployed by any sufficient movement of the delivery catheter 2 proximally relative to the inner catheter 25, thereby engaging the distal end 27 of the inner stem 28 of the inner catheter 25 with the filter element 40 to facilitate deployment of the filter element 40.

The construction of the pod 13 of the delivery catheter 2 and the inner stem 28 of the inner catheter 25 prevent deformation of the pod 13 and the inner stem 28 during deployment of the filter element 40. In particular, elongation of the pod 13 and compression of the inner stem 28 are avoided. This ensures that the filter element 40 is accurately and smoothly deployed in the desired location in the vasculature 110.

In the extended outwardly projecting position the filter body 41 is in complete circumferential apposition with the wall of the vasculature 110 over a length substantially equal to the intermediate section 53 of the filter support frame 42.

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After deployment of the filter element 40 both the delivery catheter 2 and the inner catheter 25 are retracted and withdrawn from the vasculature 110, leaving the guidewire 1 in place in the vasculature 110, and the deployed filter element 40 in place in the vasculature 110 distally of the stenosed region 111 (Figs. 40 and 41).

The guidewire 99 is not attached to the filter element 40, and thus the guidewire 99 is free to rotate and/or to move longitudinally relative to the deployed filter element 40. This is highly advantageous as it prevents any accidental movement of the guidewire 99 causing twisting and/or dislodging of the deployed filter element 40. Thus, the user has more freedom to carry out a treatment procedure on the stenosed region 111 without the risk of intimal abrasion, or of the deployed filter element 40 becoming dislodged or in some other way creating a potential flow path for embolic material around the filter element 40.

In addition, the portion of the guidewire 99 in place in the vasculature 110 proximal of the deployed filter element 40 is bare. This bare portion of the guidewire 99 facilitates the exchange of a wide variety of different medical devices, for example a treatment means, over the bare guidewire 99 while the deployed filter element 40 remains in place in the vasculature 110. Examples of such medical devices are atherectomy devices to carry out an atherectomy procedure on the stenosed region 111, or an angioplasty balloon 112 to carry out an angioplasty procedure on the stenosed region 111, as illustrated in Fig. 42, or a stent 113 to carry out a stenting procedure on the stenosed region 111, as illustrated in Fig. 43, or any possible combination of these procedures, or any other therapeutic or diagnostic

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procedure. Any embolic material released during such an interventional procedure will be collected and safely retained in the filter element 40.

CS/D
5 After completion of an interventional procedure, for example a treatment of the stenosed region 111, the retrieval catheter 3 is flushed, for example with a saline solution, using the syringe 91. In this case, the retrieval catheter 3 comprises an elongate tubular centring catheter 121. The centring catheter 121 has a tapered distal tip 122 which protrudes distally of a distal end 120 of the retrieval catheter 3 during advancement through the vasculature 110, as illustrated in Fig. 44, to prevent snagging of the retrieval catheter 3 on the stent 113, and to minimise vessel trauma.

CC/D
15 The retrieval catheter 3 is inserted into the vascular system and advanced over the bare guidewire 99 until the distal end 120 of the retrieval catheter 3 is distal of the stent 113 (Fig. 44). The retrieval catheter 3 is then further advanced distally over the guidewire 99 while maintaining the position of the centring catheter 121 until the distal end 120 of the retrieval catheter 3 is immediately proximal of the deployed filter element 40. The guidewire 99 is retracted to engage the distal stop 101 with the distal end 49 of the sleeve 43 of the filter element 40.

25 The distal stop 101 of the guidewire 99 may alternatively be engaged with the distal end 49 of the sleeve 43 of the filter element 40 by advancing the retrieval catheter 3 further distally to engage the deployed filter element 40 and push the deployed filter element 40 distally until the distal end 49 of the sleeve 43 of the filter element 40 engages the distal stop 101 of the guidewire 99. In this case no retraction of the guidewire 99 is necessary to

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engage the distal stop 101 with the distal end 49 of the sleeve 43 of the filter element 40.

5 It will be appreciated that any suitable combination of advancement of the retrieval catheter 3 and retraction of the guidewire 99 may be employed to effect engagement of the distal stop 101 of the guidewire 99 with the distal end 49 of the sleeve 43 of the filter element 40.

10 With the distal stop 101 of the guidewire 99 engaging the distal end 49 of the sleeve 43 of the filter element 40, the retrieval catheter 3 is advanced while maintaining the position of the guidewire 99 (Fig. 45). This causes the filter element 40 to collapse into the retrieval catheter 3 until the filter element 40 is retrieved into the retrieval catheter 3 (Fig. 46).

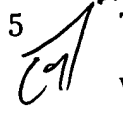
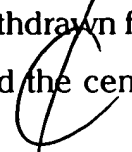
15 The filter element 40 may alternatively be retrieved into the retrieval catheter 3 by retracting the guidewire 99 while maintaining the position of the retrieval catheter 3 to collapse and retrieve the filter element 40 into the retrieval catheter 3. In this case the guidewire 99 acts to pull the filter element 40 proximally into the retrieval catheter 3.

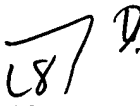
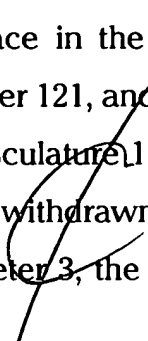
20 It will be appreciated that the filter element 40 may be retrieved by any suitable movement of the retrieval catheter 3 distally relative to the guidewire 99.

25 The distal stop 101 facilitates retrieval of the filter element 40 by preventing the filter element 40 moving distally of the distal end 100 of the guidewire 99.

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The guide olive 57 of the filter element 40 may or may not protrude distally out of the distal end 120 of the retrieval catheter 3 after collapse of the filter element 40.

5  The retrieval filter element 40 is then withdrawn from the vasculature 110 by withdrawing the retrieval catheter 3 and the centring catheter 121 together from the vasculature 110. 

 10 The guidewire 99 may be left in place in the vasculature 110 after the retrieval catheter 3, the centring catheter 121, and the retrieval filter element 40 have been withdrawn from the vasculature 110, as illustrated in Fig. 47. Alternatively the guidewire 1 may be withdrawn from the vasculature 110 upon withdrawal of the retrieval catheter 3, the centring catheter 121, and the retrieval filter element 40. 

15 When the bare guidewire 99 is left in place in the vasculature 110 after withdrawal of the retrieval catheter 3, a further treatment or diagnostic means may be advanced over the bare guidewire 99 to access any desired location in the vasculature 110. The position of the bare guidewire 99 may
20 be adjusted proximally or distally, as desired, to suit a further treatment or diagnostic procedure. Otherwise a fluroscopic assessment of the treated vessel may be made through the guiding catheter or sheath prior to withdrawal of the guidewire. This is desirable.

25 The embolic protection system of the invention offers considerable clinical advantages. The arrangement allows a clinician to select a suitable guidewire from a range of such guidewires. This provides enhanced

flexibility by ensuring that filter performance can be optimised. The embolic protection device is not dedicated to a particular guidewire.

5 Because the embolic protection device is not attached to the guidewire, the guidewire which is first advanced through a vasculature can have a low profile and be tailored to the proposed procedure or vasculature. Consequently, the guidewire can easily navigate narrow and tortuous regions of the vasculature.

10 Thus, a clinician may readily select a particular type of guidewire which provides the appropriate flexibility and performance required for a particular vascular procedure being performed. The system also facilitates the safe crossing of a lesion not only in a first lesion.

15 Another important advantage is that because the embolic protection device is not attached to the guidewire, if the embolic protection device is under-sized with respect to the region of the treatment site it is free to be carried by blood flow to a distal narrowed section of the vasculature at which the embolic protection device effectively achieves apposition with the vessel
20 wall. This ensures that all blood flow with entrained embolic material passes through the embolic protection device. The guidewire distal stop prevents movement of the embolic protection device distally off the guidewire.

25 The possibility of successfully achieving filter deployment at the intended site is significantly improved due to:

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- Initial crossing with a bare guidewire is easier as a bare guidewire has an extremely low profile, is highly trackable and highly pushable.
- Attempted crossing with a bare guidewire presents a very low risk of an embolic event due to its low profile, and atraumatic tip.
- 5 • Once the bare wire is across the lesion, crossing with the filter delivery system is simplified. Advancing the tip of the guidewire and positioning it in the distal vasculature provides additional support to the filter delivery catheter.

10 The possibility of successfully delivering other catheters and interventional devices to the lesion area is enhanced because of the independent movement compatibility of the deployed filter and guidewire. The guidewire tip can be advanced into the distal vasculature to provide anchorage during the advancement of additional catheters and devices. The filter position is maintained by visual apposition and blood flow forces.

15 In this configuration the wire provides extra support to the catheter or interventional device being advanced. This increases the possibility of delivering the catheter to the intended location and minimises the possibility of an uncontrolled proximal movement of the guidewire/filter. This uncontrolled proximal movement occurs when the guidewire has

20 insufficient support to guide an advancing catheter, through a tortuous path. With fixed wire systems the filter may be quickly withdrawn back into the lesion area with increased risk of an embolic event or stent dislodgement. The design of this invention substantially eliminates some of these serious clinical risks.

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Referring now to Figs. 48 to 56 there is illustrated other embolic protection devices which are similar to the embolic protection device of Figs. 1 to 47,

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and similar elements are assigned the same reference numerals in Figs. 48 to 56.

In the case of the embolic protection devices of Figs. 48 to 51 the lumen 56
5 of the sleeve 43 is of a diameter greater than the outer diameter of the
pushing device distal stop 72, and greater than the diameter of the
guidewire distal stop 101. Thus, the distal end 49 of the sleeve 43 is not
engageable with either the distal stop 72 of the pushing device 8 or the
distal stop 101 of the guidewire 99. Instead an engagement grip 130 is
10 provided on an inner wall of the sleeve 43, the engagement grip 130
providing an abutment for engagement with the distal stop 72 of the pushing
device 8, and for engagement with the distal stop 101 of the guidewire 99.

The engagement grip 130 may be provided at the proximal end 46 of the
15 sleeve 43 (Figs. 48 and 50) or at the distal end 49 of the sleeve 43, or at any
suitable point along the length of the sleeve 43 as desired (Figs. 49 and 51).

The engagement grip 130 may be provided by a relatively short stop rigidly
attached to the inner wall of the sleeve 43, as illustrated in Figs. 48 and 49,
20 for example by chemical means, such as an adhesive, or by mechanical
means, such as welding, or brazing, or soldering, or keying means.

Alternatively the engagement grip 130 may be provided by crimping a
portion of the sleeve 43, as illustrated in Figs. 50 and 51.

25 In the case of Figs. 52 to 54, the distal end 49 of the sleeve 43 is engageable
with the distal stop 72 of the pushing device 8, and the distal stop 101 of the
guidewire 99. However, the sleeve 43 does not extend along the length of

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the filter body 41 as far distally as in the embolic protection device of Figs. 1 to 51. The sleeve 43 may terminate close to the distal end 47 of the filter body 41 (Fig. 52), or close to the proximal end 44 of the filter body 41 (Fig. 54), or at any suitable point along the filter body 41 (Fig. 53).

5

In the case of Figs. 55 and 56, a distal portion of the lumen 56 of the sleeve 43 is of a diameter greater than the outer diameter of the pushing device distal stop 72, and greater than the diameter of the guidewire distal stop 101, and a proximal portion of the lumen 56 of the sleeve 43 is of a smaller diameter to facilitate engagement of the distal stop 72 of the pushing device 8 and engagement of the distal stop 101 of the guidewire 99 with a step 140 in the sleeve 43. The step 140 may be provided by overlapping a small diameter sleeve with a large diameter sleeve (Fig. 55), or alternatively the step 140 may be provided integral with the sleeve 43 for example by machining the step 140 into the sleeve 43.

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Referring to Fig. 57 there is illustrated the loading of an embolic protection device, which is similar to that illustrated above in Fig. 49, into the pod 13 at the distal end 12 of the delivery catheter 2. The loading procedure is similar to that described above with reference, in particular, to Figs. 28 to 34. In the case of Fig. 57, the distal stop 72 on the pushing device 8 engages the engagement grip 130 on the inner wall of the sleeve 43 to push the embolic protection device through the loading device 7 and into the delivery catheter reception space, thereby collapsing the embolic protection device, as described previously.

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FIG. 54

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Fig. 58 illustrates the loading of an embolic protection device, which is similar to that illustrated above in Fig. 48, into the pod 13 of the delivery catheter 2.

5 It will be appreciated that the engagement grip 130 may be of any suitable configuration that facilitates engagement with the distal stop 72 of the pushing device 8 for loading the embolic protection device into the pod 13 of the delivery catheter 2.

10 Referring to Figs. 59 to 62 there is illustrated an alternative loading of the filter element 40 into the pod 13 at the distal end 12 of the delivery catheter 2, which is similar to the loading procedure described above with reference, in particular, to Figs. 28 to 36. In this case, a pulling device 150 is provided in place of the pushing device 8. The pulling device 150 is similar to the
15 pushing device 8 described above, in particular with reference to Figs. 20 and 21. However, the wire 71 of the pulling device 150 extends proximally through the inner catheter 25, and out of the proximal opening 34 of the catheter for manipulation by a user.

20 The filter element 40 is loaded by pulling the pulling device 150 proximally to engage the distal stop 72 of the pulling device 150 with the distal end 49 of the sleeve 43. Further pulling of the pulling device 150 draws the filter element 40 through the loading device 7 and into the pod 13 at the distal end 12 of the delivery catheter 2, thereby collapsing the filter element 40, in
25 a manner similar to that described previously. Further pulling of the pulling device 150 proximally disassociates the loaded catheter assembly from the loading device 7 (Fig. 62), as described previously.

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Referring to Fig. 63 there is illustrated the loading of an embolic protection device, which is similar to that illustrated above in Fig. 49, into the pod 13 at the distal end 12 of the delivery catheter 2. The loading procedure is similar to that described above in Figs. 59 to 62. In the case of Fig. 63, the distal stop 72 of the pulling device 150 engages the engagement grip 130 on the inner wall of the sleeve 43 to pull the embolic protection device through the loading device 7 and into the delivery catheter reception space, thereby collapsing the embolic protection device.

Fig. 64 illustrates the loading of an embolic protection device, which is similar to that illustrated above in Fig. 48, into the pod 13 of the delivery catheter 2 using the pulling device 150.

Referring to Figs. 65 to 69 there is illustrated the retrieval of an embolic protection device, which is similar to that described above in Fig. 48, into the retrieval catheter 3. The retrieval procedure is similar to that described above with reference, in particular, to Figs. 44 to 47. In this case, the distal stop 101 on the guidewire 99 engages the engagement grip 130 on the inner wall of the sleeve 43 to prevent the embolic protection device moving distally relative to the distal stop 101 on the guidewire 1 during retrieval.

It will be appreciated that the engagement grip 130 may be of any suitable configuration that facilitates engagement with the distal stop 101 of the guidewire 99 for retrieving the deployed embolic protection device into the retrieval catheter 3.

Fig. 70 illustrates another guidewire 160 of the embolic protection system, which is similar to the guidewire 99 of Figs. 1 to 69, and similar elements are

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assigned the same reference numerals in Fig. 70. In this case, the guidewire 160 does not comprise a step from a small diameter portion to a large diameter portion.

5 Figs. 71 to 74 illustrate the deployment of an embolic protection device of the embolic protection system which has been delivered over the guidewire 160 of Fig. 70. The delivery and deployment procedure is similar to that described above with reference, in particular to Figs. 36 to 41. In this case, however, a tapered ring 161 is provided slidably mounted on the guidewire
10 160 between the distal end 27 of the inner stem 28 of the inner catheter 25 and a proximal end 163 of the embolic protection device.

To deploy the embolic protection device at a desired location in the vasculature 110, the delivery catheter 2 is retracted while maintaining the
15 position of the inner catheter 25. The retraction of the delivery catheter 2 initially draws the embolic protection device proximally due to the frictional force acting between the pod 13 of the delivery catheter 2 and the embolic protection device (Fig. 71). As the embolic protection device is initially drawn proximally it abuts the tapered ring and pushes the tapered ring 161
20 proximally until the tapered ring 161 abuts the distal end 27 of the inner stem 28 of the inner catheter 25 (Fig. 72). Further retraction of the delivery catheter 2 while maintaining the position of the inner catheter 25 causes the embolic protection device and the tapered ring 161 to slide relative to one another along a tapered plane of contact 162. This movement exerts an
25 inward force on the tapered ring 161 to lockingly engage the tapered ring 161 to the guidewire 160. In this way the embolic protection device is taper-locked to the guidewire 160 by means of an interference fit between the embolic protection device and the tapered ring 161, and by means of an

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interference fit between the tapered ring 161 and the guidewire 160 (Fig. 73). The delivery catheter 2 and the inner catheter 25 may then be withdrawn from the vasculature 110 to leave the deployed embolic protection device engaged to the bare guidewire 160 in place in the vasculature 110 (Fig. 74).

The embolic protection device is retrieved in a manner similar to that described previously with reference to Figs. 44 to 47. The retrieval catheter 3 is advanced over the guidewire 160 until the retrieval catheter 3 is proximally adjacent the deployed embolic protection device. The retrieval catheter 3 is then further advanced while maintaining the position of the guidewire 160 to collapse and retrieve the embolic protection device into the retrieval catheter 3. Because the embolic protection device is taper-locked to the guidewire 160 it is not necessary to provide a distal stop on the guidewire 160 for abutment with the embolic protection device. The taper-lock ensures no movement of the deployed embolic protection device distally relative to the guidewire 160 is possible, and thus facilitates retrieval of the embolic protection device into the retrieval catheter 3. The retrieved embolic protection device is then withdrawn from the vasculature 110 by withdrawing the retrieval catheter 3 and the guidewire 160 together.

Referring to Figs. 75 to 77 there is illustrated an embolic protection system which is similar to the embolic protection system described above with reference to Figs. 71 to 74, and similar elements are assigned the same reference numerals in Figs. 75 to 77. In this case the embolic protection system comprises two tethers 170 with inwardly arcing hooks 172 at distal ends of the tethers 170, the tethers 170 extending between the inner catheter 25 and the delivery catheter 2. The embolic protection device

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comprises co-operating recesses 171 in the proximal end 163 of the embolic protection device for receiving the tether hooks 172, as illustrated in Fig. 76.

Deployment of the embolic protection device proceeds in a manner similar to that described above with reference to Figs. 71 to 74. During retraction of the delivery catheter 2, the tethers 170 are also retracted to ensure that the embolic protection device is drawn proximally to effect a secure taper-lock of the embolic protection device to the guidewire 160 (Fig. 76). The tethers 170 act in addition to the frictional force between the pod 13 of the delivery catheter 2 and the embolic protection device to draw the embolic protection device proximally.

After deployment and taper-locking of the embolic protection device, the hooks 172 of the tethers 170 are unclipped by advancing the inner catheter 25 (Figs. 76 and 77). The distal end 27 of the inner stem 28 of the inner catheter 25 engages the hooks 172 and levers the hooks 172 outwardly disengaging the hooks 172 from the co-operating recesses 171 (Fig. 77). The tethers 170 and the inner catheter 25 are then withdrawn from the vasculature 110 to leave the deployed embolic protection device in place in the vasculature 110 taper-locked to the bare guidewire 160.

Referring to Figs. 78 to 81 there is illustrated a rapid exchange embolic protection system which is similar to the embolic protection systems of Figs. 1 to 77, and similar elements are assigned the same reference numerals in Figs. 78 to 81. In this case, the pod 13 of the delivery catheter 2 comprises an elongate slit 180 and the inner stem 28 of the inner catheter 25 comprises a rapid exchange aperture 181 for passage of a guidewire 182 through the aperture 181 and the slit 180 (Fig. 78).

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The embolic protection device is delivered to a desired location in the vasculature 110 distally of the stenosed region 111 (Fig. 78) in a manner similar to that described previously with reference to Figs. 36 and 37. The embolic protection device is deployed by retracting the delivery catheter 2 while maintaining the position of the inner catheter 25 (Figs. 79 to 81), which facilitates deployment of the embolic protection device in a manner similar to that described previously with reference to Figs. 38 and 39.

The slit 180 in the pod 13 of the delivery catheter 2 is aligned with the rapid exchange aperture 181 in the stem 28 of the inner catheter 25 to prevent occlusion of the rapid exchange aperture 181 during the relative movement of the delivery catheter 2 and the inner catheter 25.

The aperture 181 provided in a sidewall of inner stem 28 of inner catheter is preferably located at a position along the length of the inner catheter which is spaced a relatively longer distance from the proximal end of the catheter than from the distal end of the catheter. Additionally, delivery catheter 2 desirably incorporates an elongate slit 180 which is located adjacent the distal end the catheter and co-operates with aperture 181 and the guide wire 182 which exits therethrough to facilitate a rapid exchange of the catheter and filter assembly over the guide wire, thereby promoting ease of exchange without the necessity of utilising exchange wires or extension wires. As illustrated in Figs. 78-81, this arrangement permits use of rapid exchange wire techniques as well as controlled deployment and retrieval of the filter at the delivery pod portion 13 located at the distal end of delivery catheter 2.

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This is advantageous in that it facilitates single operator use. A shorter guidewire may be used than for conventional systems making the device less cumbersome.

5 Referring now to Fig. 82 there is illustrated another embolic protection system 200 according to the invention. The system is similar to these described above and like parts are assigned the same reference numerals. In this case the guidewire 99 includes a proximal stop provided by a step 201 and the filter has a proximal engagement element provided by integral
10 projections 202 which extend radially inwardly. The projections 202 are configured to pass over the proximal step 201 when the filter element is being moved distally over the guidewire 99 for deployment but are prevented from moving proximally over the proximal step 201. Thus, the filter element, on deployment can move between the proximal and distal stops on the guidewire. The arrangement may allow the filter to be
15 retrieved over the proximal step 202.

Referring to Fig. 83 there is illustrated a system 205 similar to that of Fig. 82 and like parts are assigned the same reference numerals. In this case the
20 proximal step on the guidewire is provided by a proximally tapering element 206.

The embolic protection device is not restricted to use with a particular guidewire because it is not attached or engaged with the guidewire in any
25 way as it is advanced over the guidewire. This is a highly advantageous arrangement. If the guidewire proves unsuitable for some reason, for example because it is too large or not trackable enough to access a desired site in a vascular system, the guidewire may be replaced with a more

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suitable guidewire, for example a guidewire with greater flexibility. However, because the embolic protection device is independent of the guidewire it may be used with any suitable guidewire.

5 The invention gives greater freedom to a user by providing a choice of guidewires to suit a patient anatomy without requiring the user to select the embolic protection device to be used with the guidewire until after successful crossing of a lesion with the guidewire.

10 Numerous vascular catheter functions are facilitated by the invention, such as:

(i) Permits Dye Injections:

15 After performing a therapeutic procedure (e.g. angioplasty or atherectomy), the embolic protection device can be retrieved if desired, in order to inject dye (over the remaining guidewire), such that minimal obstruction or interference occurs with the subsequent dye flow measurements. Alternatively, the wire can also be safely partially-retracted “behind” or
20 “upstream” of the treated area, prior to performing the dye injection.

(ii) Delivery of Lytic Agents:

25 Depending upon therapeutic needs, lytic agents can be site-specifically delivered to a region of interest, either with the embolic protection device deployed, or with the embolic protection device retrieved, if desired.

(iii) Facilitates Stent Procedures:

Assuming appropriate design considerations have been incorporated, the retrieval sheath can also facilitate safe removal of the embolic protection device following a stenting procedure. For example, after deployment of an intravascular stent, the process of removing the embolic protection device favours certain sheath designs, such as a tapered distal tip. Specifically, the distal tip of the sheath needs to permit easy crossing of the stent in a manner which will not catch up or "snag" at the proximal edge of the implanted stent, nor along any inwardly-projecting surface of the interior of the implanted stent, as the sheath is being introduced. More specifically, the distal region of the retrieval sheath is also preferably formed of a material which permits radial expansion at the distal tip in order to accommodate retrieval of the embolic protection device.

(iv) Facilitates Guidewire Replacements:

Because this embolic protection system accommodates barewire introduction, it is possible to replace a guidewire during a procedure, if desired. For example, during treatment of two or more, distally spaced-apart lesions, it may become necessary to replace the initial guidewire during the procedure with another guidewire offering improved steering or distal flexibility. The present invention might support such guidewire replacements as follows. First, the embolic protection device is retrieved into the retrieval sheath (which has already crossed the first lesion area). Then the wire can be withdrawn (or alternatively, the wire and embolic protection device together can be withdrawn), while the sheath remains across the lesion. Subsequently, a replacement guidewire can be introduced through the sheath lumen to the area of interest.

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A number of engagement means between the embolic protection device and the guidewire are described above which ensure that the embolic protection device is anchored or tethered while the retrieval sheath is advanced over the embolic protection device. It is also envisaged that an engagement means may be provided between the embolic protection device and the retrieval sheath after the filter is retrieved, to ensure that there is a positive engagement between the embolic protection device and the sheath. For example, frictional engagement means may be provided on one or both of the embolic protection device and sheath. For example, projections, rings, or the like may be provided on the inner surface of the retrieval sheath adjacent the distal end thereof to provide a frictional fit with the retrieved embolic protection device. Typical arrangements 210, 220 of this type are illustrated in Figs. 84 and 85. The frictional engagement may be provided by projections 225 which may be of any type including continuous, discontinuous, radially and/or longitudinally extending.

The invention is not limited to the embodiments hereinbefore described, which may be varied in construction and detail.